Triassic-Jurassic extension and Alpine inversion in Northern Morocco

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ABSTRACT

The Early Mesozoic half-grabens of northern Morocco form part of the regional extensional system which developed in conjunction with the opening of the Western Tethys. During the Tertiary, Alpine collision of the African and European plates, these half-graben system were inverted, giving rise to the uplift of the High and the Middle Atlas mountains. Similar, albeit less spectacular inversion features occur in the Guercif area and in the "Rides Prérifaines" of northern Morocco. Reflection seismic data show that inversion of the Guercif Basin involved the reactivations Mesozoic basement faults. In contrast, the "Rides Prérifaines" correspond to an extensive detachment system which is decoupled from the basement at the level of the Triassic evaporites. The geometry of this complex system of Late Miocene-Pliocene thrust faults and associated lateral ramps was preconditioned by the configuration of the Triassic-Jurassic extensional faults.

Detailed structural and stratigraphic analyses, combining surface geology and seismic data, greatly advanced the understanding of the geological history Northern Morocco and has led a reassessment of its hydrocarbon potential.

INTRODUCTION

The main structural elements of northern Morocco are the Moroccan Meseta, the Rif fold and thrust belt and the northeastern part of the Middle Atlas Mountains (Fig. 1).

The Moroccan Meseta is upheld by the outcropping, peneplained Hercynian basement and its Mesozoic cover. To the North, the Meseta dips gently under the Neogene fill of the Rif foreland basin which is underlain by a thin Mesozoic cover. This basin is subdivided into the Rharb Basin in southwest, the south-central Saiss Basin and the Guercif Basin in the northeast. These basins are filled by an upwards shallowing Late Miocene to Pleistocene sequence, commencing with deep-water pelagic sediments which are followed by alluvial-fluvial and finally lacustrine deposits. In the Rharb Basin, these sediments were deposited in

Zizi, M., 1996. — Triassic-Jurassic extension and Alpine inversion in Northern Morocco. *In*: Ziegler, P. A. & Horvàth, F. (eds), Peri-Tethys Memoir 2: Structure and Prospects of Alpine Basins and Forelands. *Mém. Mus. natn. Hist. nat.*, **170**: 87-101 + Enclosures 1-4. Paris ISBN: 2-85653-507-0.

This article includes 4 enclosures on 2 folded sheets.

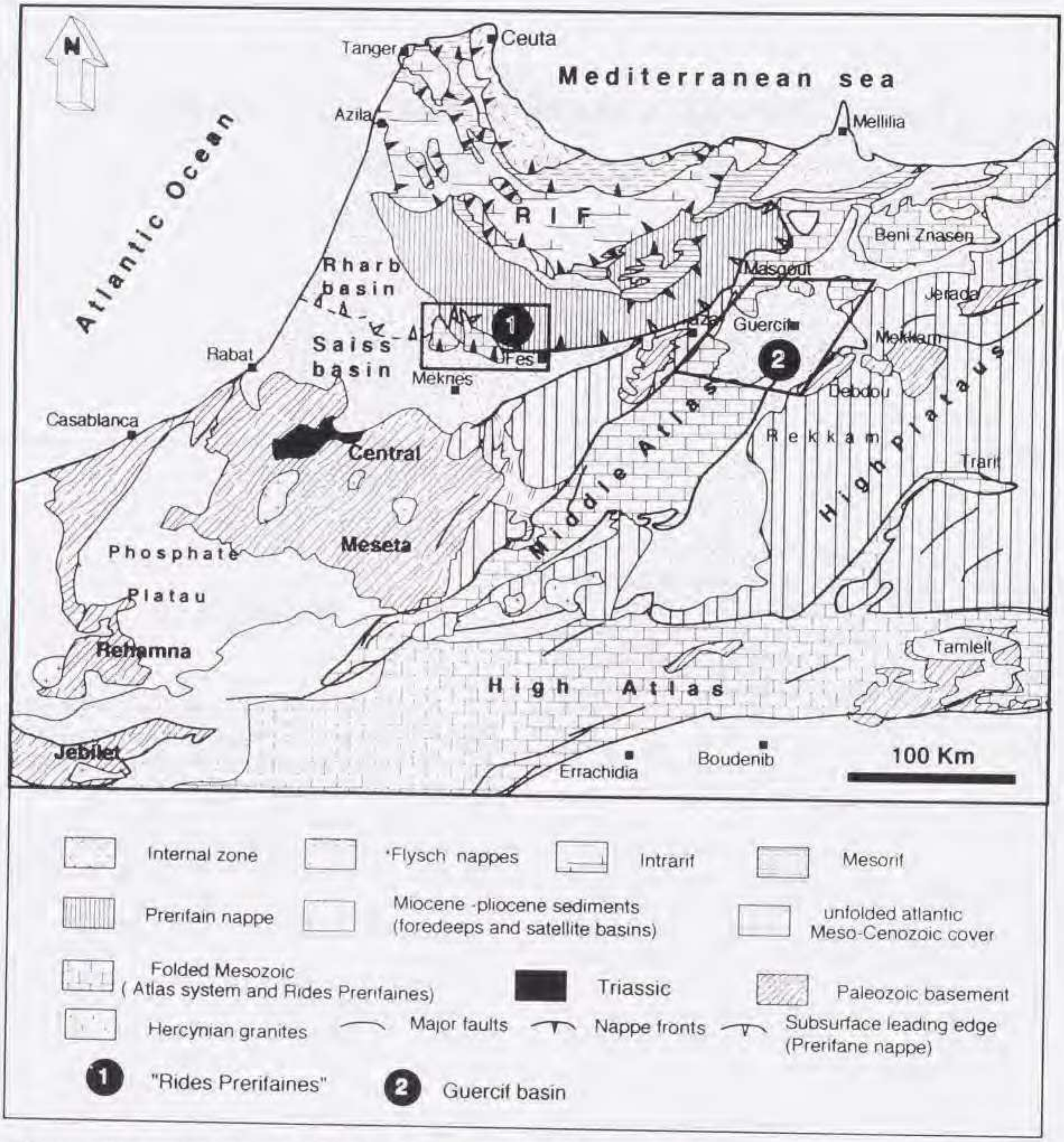


FIG. 1. Major tectonic element of Northern Morocco, showing location of study areas (modified after Michard, 1975)

extensional satellite basins on top of the chaotic "Nappe Prérifaine" (Flinch, 1993, this volume).

The "Rides Prérifaines", translated from the French as the "Fore-Rif ridges", form the mountainous terrain which extends from the Sidi Kacem to Fes. These mountains are upheld by folded and thrust-faulted shallow water Mesozoic carbonates which are capped by Cenozoic sediments and the chaotic Prérifaine nappe. Most authors interpreted the "Rides Prérifaines" as south-west, south and east verging thrust sheets (Sutter, 1980a and 1980b).

The southwest-northeast striking Middle Atlas Mountains are located to the southeast of the Neogene Rif foreland. These mountains developed in response to Late Cretaceous and Paleogene inversion of a system of deep Triassic to Jurassic half-grabens. To the southeast, the Middle Atlas is bordered by the High Plateau, a stable block which is characterized by a relatively thin Mesozoic sedimentary cover, consisting of Triassic-Early Lias redbeds and volcanics and Jurassic carbonates, which rests on peneplained Palaeozoic rocks. The Guercif Basin is a Late Neogene depression which is superimposed on the northeastern part of the inverted Middle Atlas Trough.

STRATIGRAPHIC FRAMEWORK

The Mesozoic and Cenozoic sediments of northwestern Morocco rest unconformably on the peneplained surface of the Hercynian basement. As evident from outcrops on the Moroccan Meseta, this basement consists of deformed Carboniferous, Devonian and Cambrian clastics and carbonates which are intruded by Hercynian granites (Piqué, 1982; Laville and Piqué, 1991). During latest Carboniferous and Permian times, accumulation of continental clastics in small intramontane basins was accompanied by the intrusion of acidic plutons (Cousminer and Manspeizer, 1977; Van Houten, 1977).

During the Triassic and Early Jurassic, the evolution of northern Morocco was dominated by rifting activity which was intimately related to the early phases of the Pangea breakup (Ziegler, 1988; Dercourt et al., 1993). Extensional tectonics, accompanied by the intrusion and extrusion of tholeiitic basalts, controlled the subsidence of the Middle and High Atlas Troughs and the external Rif system of grabens and half-grabens (Beauchamp, 1988; Favre et al., 1991; Laville and Piqué, 1991). Marine transgression entered these grabens during the Late Triassic, giving rise to the accumulation of a thick evaporitic series which laterally grades into continental red beds (Fig. 2). During the Early Jurassic, open marine conditions were established; whereas deeper water shales and carbonates accumulated in the continuously subsiding grabens, carbonate platforms developed on the graben flanks (Favre and Stampfli, 1992). Triassic and Early Jurassic sediments range in thickness between 200 m and 2000 m.

With the early Middle Jurassic onset of sea floor spreading in the Central Atlantic (Emery and Uchupi, 1984), rifting activity ceased in Morocco. However, continued tectonic activity, resulting in the subsidence of small transtensional basins, must be related to the sinistral translation of Africa relative to Europe in response to progressive opening of the Central Atlantic and the Western Tethys (Ziegler, 1988; Laville and Piqué, 1991; Dercourt et al., 1993). During the Middle and Late Jurassic times, the grabens of Morocco were gradually filled in with clastics derived from southern sources and later by platform carbonates, as evident by the stratigraphic record of the Middle Atlas, Guercif and the external Rif basins (Fig. 2).

With the Late Senonian onset of counter-clockwise convergence of Africa-Arabia with Eurasia, the Alboran-Kabylia Block began to move westwards with respect to North Africa and started to converge with Iberia and northwestern Africa (Wildi, 1983; Ziegler, 1988, 1990). Paleocene-Early Eocene collision of the Alboran Block with the Moroccan Tethys margin was accompanied by the development of an accretionary wedge, corresponding to the Rif flysch nappes, the subsidence of the Rif foreland basin and inversion of the Middle Atlas Trough.

In the distal parts of the Rif foreland basin, corresponding to the domain of the "Rides Prérifaines", Middle Miocene (Langian-Serravalian) shallow water carbonate and clastic sediments transgressed over truncated Mesozoic strata; in

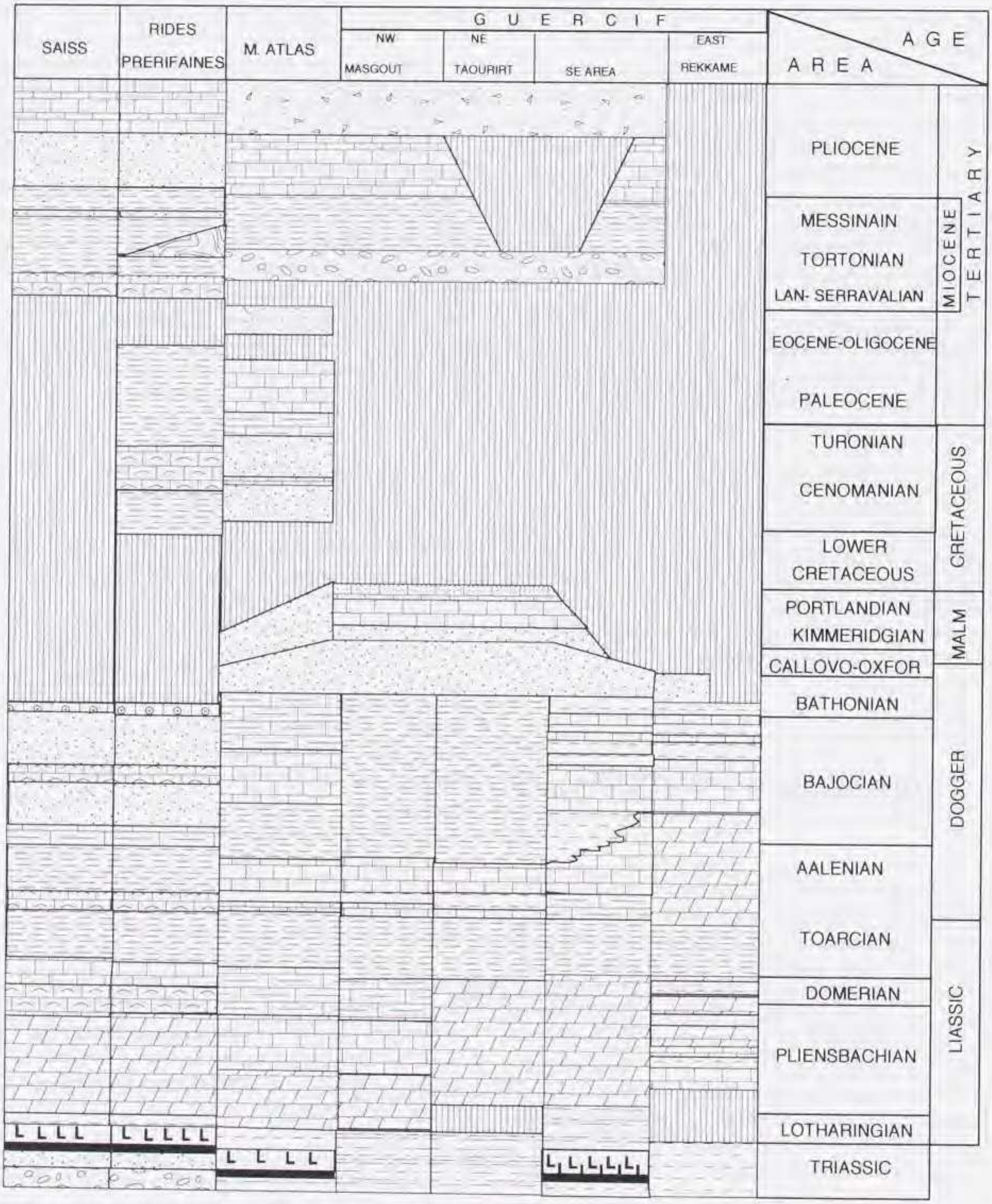


FIG. 2. Chronostratigraphy of post-Hercynian series of Northern Morocco ("Rides Prerifaines", Middle Atlas and Guercif Basin).

turn, these are covered by Tortonian basinal marls. During their accumulation, the Prérifaine nappe was emplaced. This nappe consists of an up 2000 m thick chaotic assemblage of blocks, varying in size from 1 m to 100 m, embedded in Tortonian marls. Most common components are Triassic red beds, evaporites and volcanics. In turn, the Prérifaine nappe is covered by Tortonian-Messinian blue marls which grade upwards into the Early Pliocene epicontinental sands and Late Pliocene lacustrine limestones. Accumulation of this post-nappe sequence, which attains thicknesses of up to 1500 m, was contemporaneous with Messinian-Pliocene foreland compressional phases. Quaternary travertines, conglomerates, and yellowish sands of presumably Villafranchian age, rest disconformably on truncated Pliocene strata.

During these late deformation phases, Triassic salt provided a regional detachment level. The Early Mesozoic rift geometry and the distribution of the Triassic salt played an important role in guiding the geometry of the developing thrust structures.

In the Guercif Basin, Tortonian to Pliocene alluvial, deltaic and coastal sediments, reaching a thickness of up to 2000 m, were deposited under a tensional regime during Tortonian times and under a compressional regime in Pliocene times. This basin is superimposed on the northeastern parts of the inverted Middle Atlas Trough.

This paper integrates the surface geology of the "Rides Prérifaines" and the Guercif Basin with reflection-seismic data imaging the subsurface structures and documenting the larger scale geometry and the areal extend of these features. Our interpretation are based on seismic grids which cover the entire "Rides Prérifaines" and the Guercif Basin. Selected lines of these grids and their interpretation are provided by Enclosures 1 to 4.

STRUCTURE AND EVOLUTION THE "RIDES PRÉRIFAINES"

Surface geological studies of the "Rides Prérifaines" date back to the late 1920's. Daguin (1927), Levy and Tilloy (1952), Durand Delga et al. (1960, 1962) and Sutter (1980a and 1980b) all suggested a compressional origin for the "Rides Prérifaines". On the other hand, Faugère (1978) proposed that these structures resulted from the interactions of two basement-involving strike-slip systems, located along the southern and western margin of the "Rides Prérifaines". According to this author, movements along these faults were transmitted to the Mesozoic series which, due to their decoupling from the basement by the Triassic salt, display more complex structures. All authors agree that the formation of the "Rides Prérifaines" is of Messinian to Plio-Pleistocene age and post-dates the major tectonic phases which controlled the evolution of the Rif fold and thrust-belt.

Ait Brahim and Chotin (1984) carried out a microtectonic study of the "Rides Prérifaines" and identified four compressional phases, characterized by principal horizontal compressional stress trajectories changing from NW-SE during pre- Miocene times, to N-S during the Late Tortonian, to E-W during the Messinian and to NE-SW during the Plio-Pleistocene.

Figure 3 provides a tectonic map of the "Rides Prérifaines", showing their main structural elements and the location of reflection-seismic lines discussed below. The autochthonous foreland of the Saiss plain lies to the south of the "Rides Prérifaines". The northeastern parts of the "Rides Prérifaines" are overridden by the chaotic Prérifaine nappe on which the Late Miocene to Pleistocene post-nappe satellite basins subsided (Flinch, 1993, this volume).

The seismic profiles, given in Enclosures 1 and 2, show that the dominantly NE-SW and E-W trending surface structures are superimposed on Early Mesozoic extensional fault systems. Seismic line P-12 (Enclosure 1) crosses the "Rides Prérifaines" in an east-westerly direction and covers the eastern part of the Rharb Basin, the Bou Draa, Tselfat and Mesrana anticlines and the northern parts of the Nzala des Oudayas structure. This profile shows that the "Rides Prérifaines" consist of two large, superimposed thrust sheets, namely the Prérifaine nappe and the Late Miocene-Pliocene thrust belt which involves the sedimentary fill of the Mesozoic grabens, the "Aquitanian-Burdigalian" (Languian-Serravalian, according to recent palaeontologic studies) foreland basin, as well as

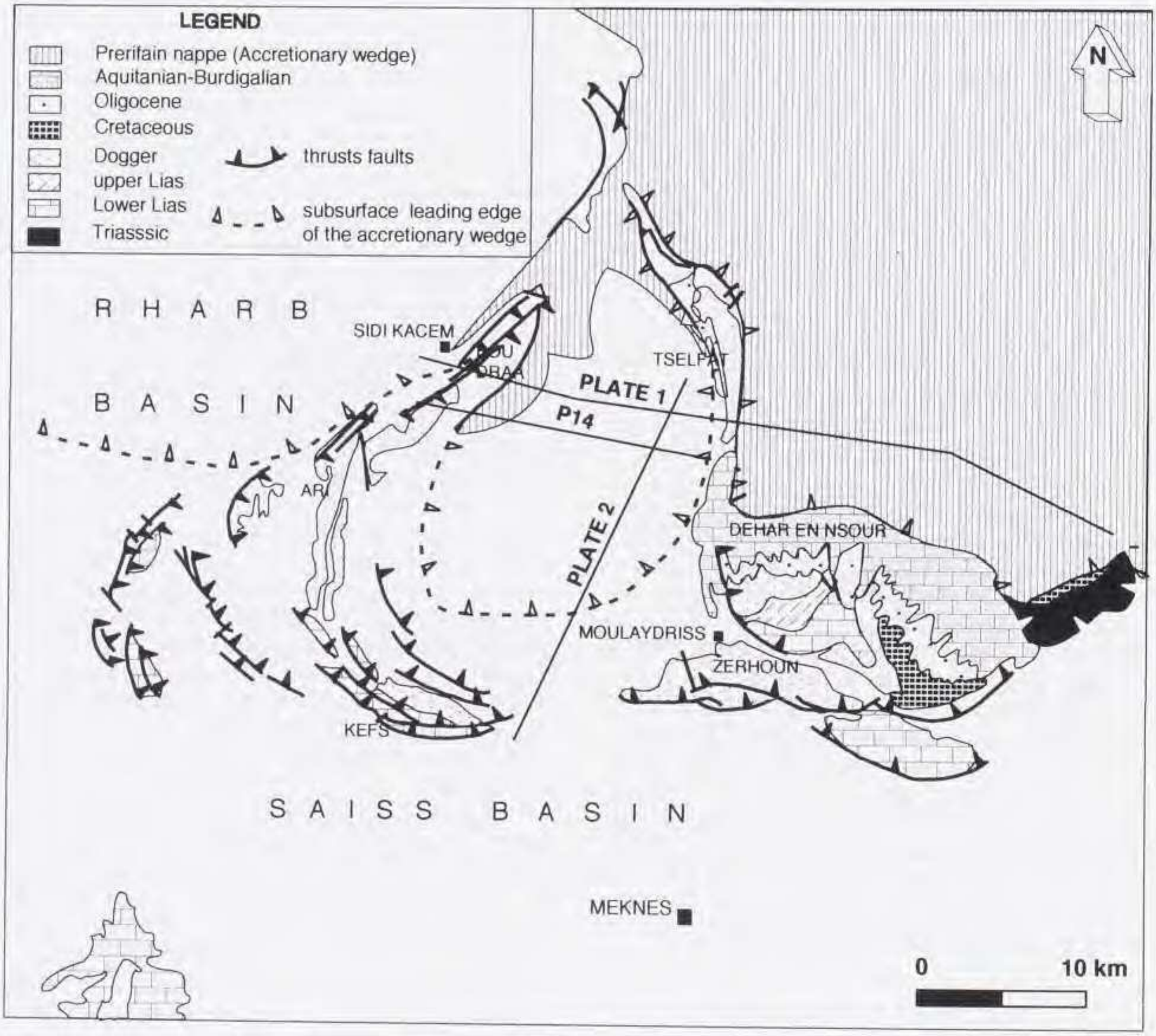


FIG. 3. Tectonic map of "Rides Prérifaines", showing location of seismic lines given in Enclosures 1 and 2 and Fig. 5.

the Prérifaine nappe. This late compressional deformation was contemporaneous with the deposition of the Late Miocene-Pliocene sedimentary series (line P-15, Enclosure 2). The entire sedimentary package, including the allochthonous accretionary wedge of the Prérifaine nappe, is detached from the autochthonous basement at the level of Triassic evaporites.

The thrusted Bou Draa and Tselfat ridges are superimposed on Triassic normal faults, offsetting the top of the basement. The broad and the gentle Mesarna structure, defined at intra-Jurassic levels, is associated with lateral thicknesses changes which are more pronounced at Toarcian and Aaleno-Bajocian levels than in the Domerian; these thickness changes are interpreted as reflecting intra-Jurassic salt movements. However, as the base of the Prérifaine nappe is also deformed, a Neogene growth component can be postulated for the Mesarna structure. To the South of line P-12, where Triassic salts are involved in this structure, unconformities within the Late Mio-Pliocene sediments give good evidences for reactivation of salt movements at the time of the development of the thrusted Bou Draa and Tselfat structures.

The northwest-verging the Bou Draa structure is evidently associated with a sharp increase in thickness of the Triassic-Jurassic sediments across a deep seated basement fault. This fault is part of the Sidi Fili fault system which, decades ago, had been identified by petroleum geologists.

The seismic profile P-15 (Enclosure 2), which

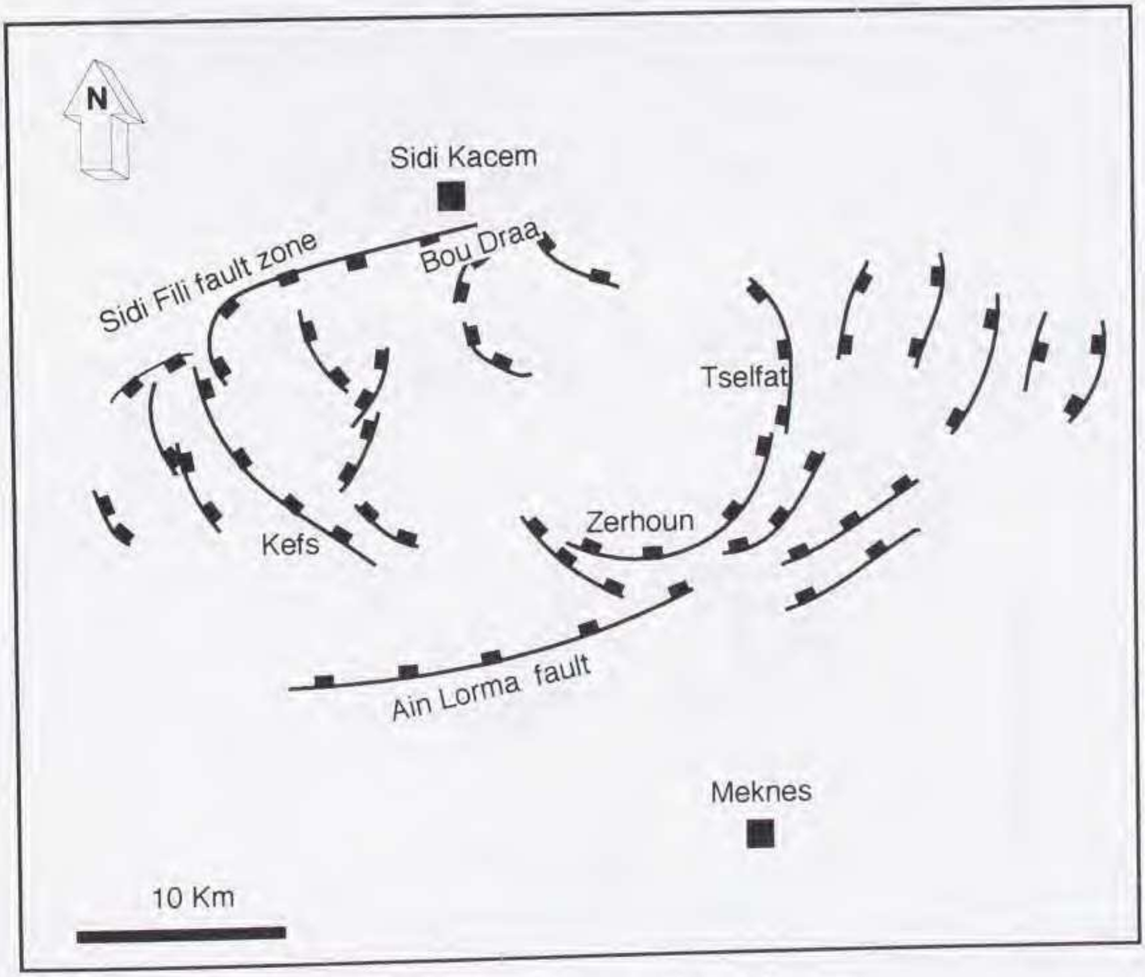
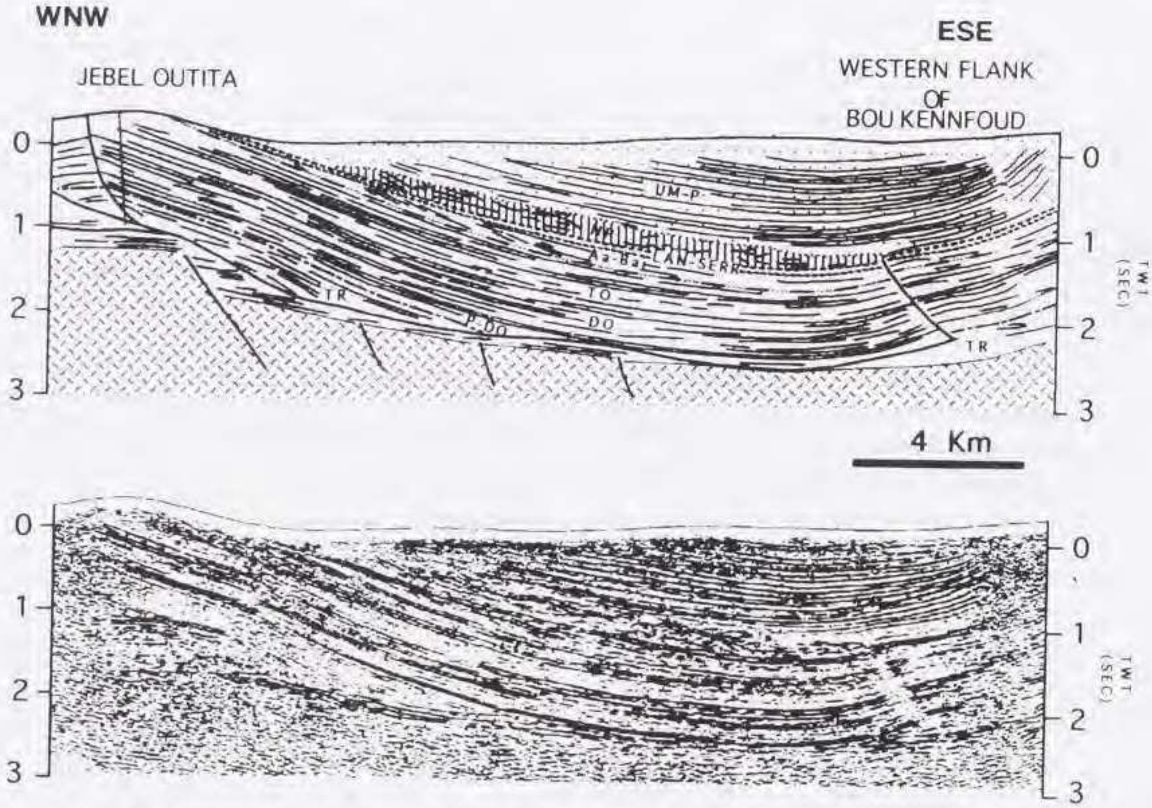


FIG. 4. Triassic-Jurassic normal fault pattern of "Rides Prérifaines", based on reflection-seismic data.



ABREVIATIONS:
TR : TRIASSIC ; P-DO : PREDOMERIAN ; DO : DOMERIAN ; TO : TOARCIAN
Aa-Baj : AALENO- BAJOCIAN ; LAN-SERR : LANGHIAN- SERRAVALIAN
NP : NAPPE PRERIFAINE ; UM-P : UPPER MIOCENE-PLIOCENE.

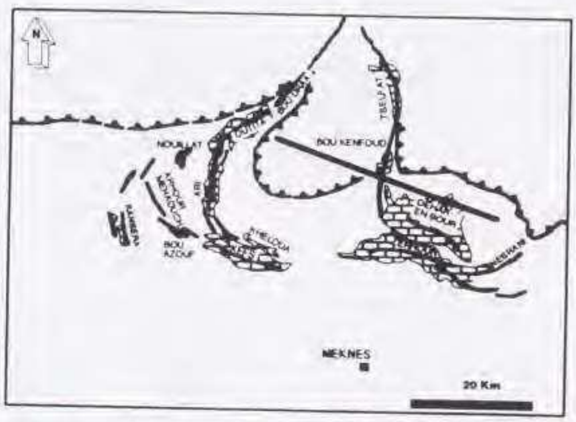


FIG. 5. E-W profile throgh "Rides Prérifaines", illustrating block-faulted basement, sub-horizontal reflectors beneath intra-salt decollement horizon, progradation to the east of the Aaleno-Bajocian sequence, convergence of Late Miocene-Pliocene sequence towards the western flank of the Bou Kennfoud structure.

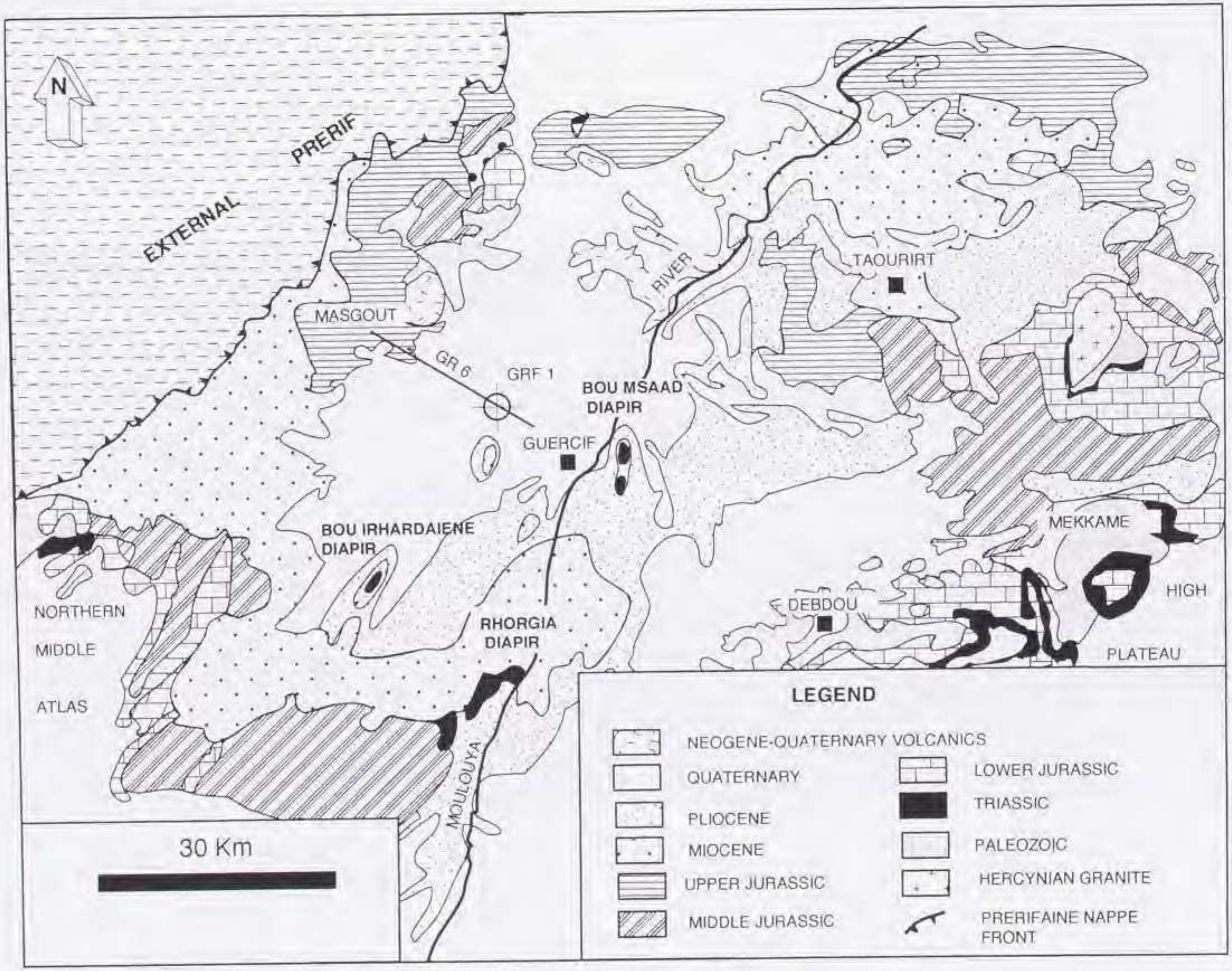


FIG. 6. Geological map of Guercif Basin, showing location of outcropping diapirs and seismic line given in Fig. 7.

crosses the "Rides Prérifaines" in a northeasterly direction, shows that also the southerly verging thrust faults, which carry the Kefs and Kheloua structures, ramp up from the Triassic evaporites through Jurassic strata above a set of normal basement faults. Also the largely salt induced Nzala des Oudaya structures are associated with Triassic normal faults offsetting the basement (Enclosure 1).

The Triassic-Jurassic fault map, given in Fig. 4, is based on an interpretation of the entire seismic grid. It illustrate that the Early Mesozoic fault system consists of west, east and north hading normal faults, the length of which varies between 2 km and 20 km. The Sidi Fili fault trend defines northwestern margin of the Triassic-Early Jurassic "Rides Prérifaines" half graben system.

On seismic lines, the Prérifaine nappe is characterized by discontinuous to chaotic reflectivity, abounding with diffractions (Fig. 5). Its southern termination is clearly evident on the line P-15 (Enclosure 2); this allochthonous body is laterally offset and onlapped by Tortonian series, characterized by parallel and laterally continuous reflectors. The base of the nappe corresponds to the smooth surface which forms the top of the "Aquitanian-Burdigalian" reflectors. This clearly shows that this allochthonous unit was emplaced in post-Middle Miocene and pre-Late Miocene times (Flinch, 1993, this volume), that is, during a relatively short time span. Emplacement of this nappe was accompanied by drowning out of the foreland platform and its rapid subsidence to considerable water depth.

The Late Miocene to Pliocene series, which covers the Prérifaine nappe, is characterized parallel to sub-parallel reflectors which generally converge towards the top of "Rides Prérifaines" anticlines (Enclosure 2). Significant syn-depositional deformation is indicated by the convergence of reflectors and the presence of unconformities within this Mio-Pliocene series, as shown by the growth of the syncline away from the anticlines (Enclosure 2). Moreover, the thrust fault carrying the Bou Draa structure (Enclosure 1) clearly cuts through the Prérifaine nappe and the Late Mio-Pliocene series. Therefore, deformation of the "Rides Prérifaines" clearly post-dates the emplacement of the Prérifaine nappe. This was already evident from surface geology (e.g. Levy and Tilloy, 1952; Sutter, 1980).

The northerly striking structures of "Rides Prérifaines" are generally associated with preexisting salt pillows, some of which are superimposed on normal basement faults. Line P-12 and P-15 show that during the Late Miocene-Pliocene deformation of the "Rides Prérifaines" the Mesozoic and younger series were decoupled from the basement at the level of Triassic salts. Although there is no evidence for the reactivation of normal faults affecting the basement, their intra sedimentary part was clearly reactivated and played an important role in localizing the deformation of structures which now form the "Rides Prérifaines" (Fig. 5). As such, the entire system of the "Rides Prérifaines" must be considered as a thin-skinned thrust belt which partly scooped out the sedimentary fill of the Triassic-Early Jurassic Prérifaine grabens. The thrusted folds forming the western and eastern structures correspond to lateral ramps whereas the southern structures form the frontal ramps of this thin-skinned thrust belt.

EVOLUTION OF THE GUERCIF BASIN

The Guercif Basin contains up to 2000 m of Tortonian to Pliocene sediments and is superimposed on the northeastern parts of the Early Mesozoic Middle Atlas Trough which was inverted during Paleogene times (Figs. 6 and 7).

Development of the Middle Atlas Mountains is generally thought to result from the sinistral transpressional deformation from an Early Mesozoic rifted basin (Mattauer et al., 1977; Jacobshagen, 1988; Fedan, 1988; Boccaletti et al., 1990; Bernini et al., 1994). Choubert and Faure-Muret (1962) visualize Late Eocene, Late Oligocene and Middle Miocene compressional phases whereas du Dresnay (1988) recognized Late Senonian precursor events followed by a major Late Eocene phase of basin inversion.

The tectonic history of the Neogene Guercif Basin was studied by Colletta (1977) who identified a Late Tortonian to Messinian extensional phase, a late Pliocene compressional episode and possibly renewed extension during the Quaternary.

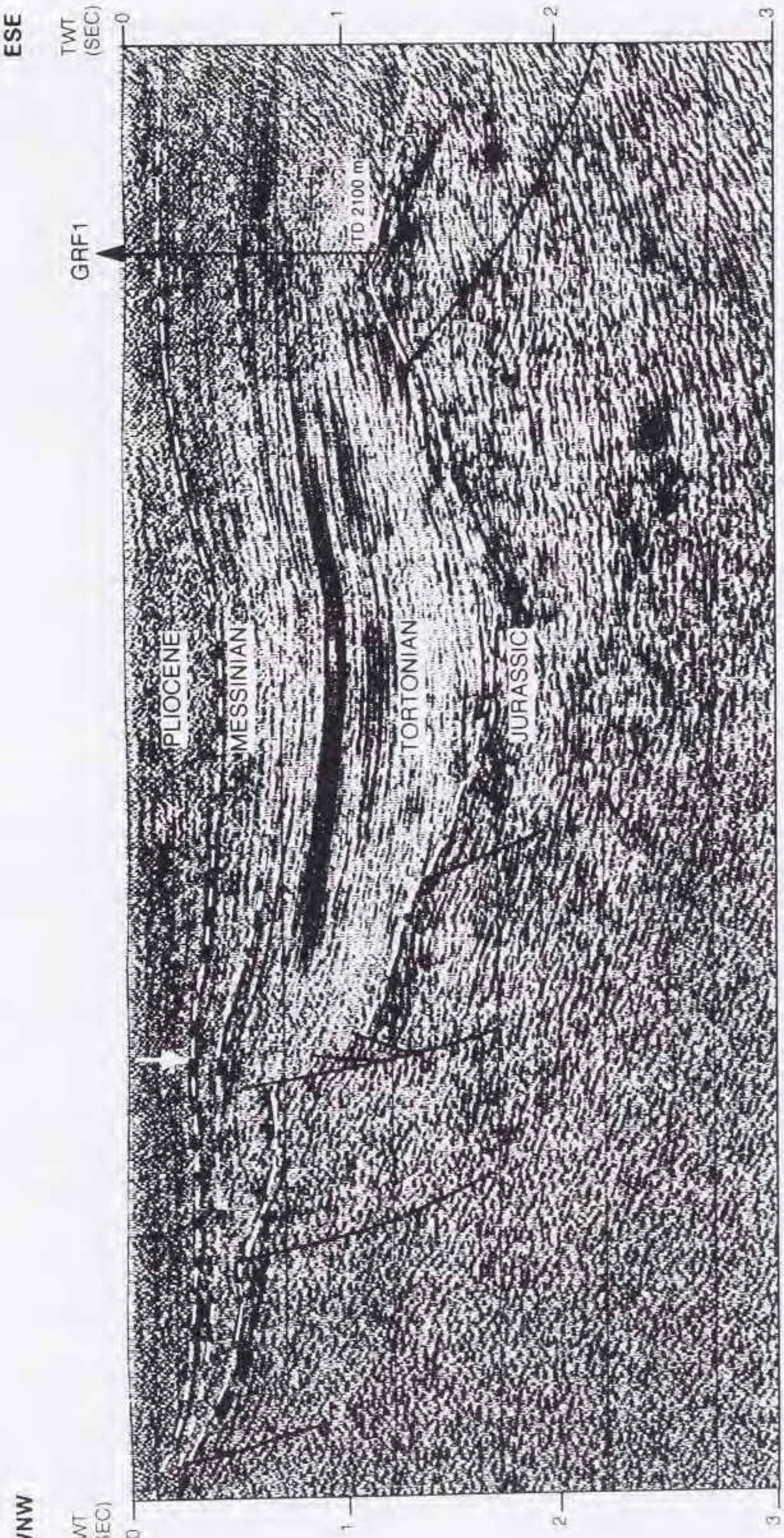


FIG. 7. Reflection-seismic line through Guercif Basin, illustrating Tortonian extension and Pliocene compression. Note minor inversion of Tortonian graben below white arrow. (for location see Fig. 6).

Mokhtari (1990), Boccaletti et al. (1990) and Bernini et al. (1994) all interpreted the Guercif Basin structures in terms of flower structures. Bally (1992) described the structures of the Guercif Basin as mini-inversion structures, involving the reactivation of Mesozoic extensional faults during pre-Tortonian inversion movements, however, without fully compensating their Mesozoic offsets.

The following discussion on the evolution of the Guercif area is based on the analysis of a grid of reflection-seismic profiles which are partly calibrated by wells.

Lack of well control impedes precise dating of the presumably Late Triassic-earliest Jurassic onset of the rifting activity in the northeastern parts of the Middle Atlas Trough (line G-17, Enclosure 3). Strong thickness changes across the fault limiting the Debdou platforms suggests that differential subsidence of the Middle Atlas half-graben persisted into early Late Jurassic times; diverging intra-Jurassic reflectors and a number of unconformities are taken as evidence for syn-sedimentary extension. An unconformity at the base of the Bathonian to Late Jurassic sequence indicates continued tectonic instability of the area.

Some salt-cored anticlines have been mapped in the western Guercif Basin (Fig. 6). Line G-5 (Enclosure 4) gives a good impression of these structures even though the seismic data are not very good. This section crosses the outcropping Rhorgia diapir to the SW and the Bou Msaad diapir to the East. The presence of a third diapir between these two structures is suggested. Note the interpreted thinning of the lower Liassic-Domerian interval towards the western domes and the thickening of the Bathonian-Portlandian section along the southwestern flank of the central salt structure. The thinning of the Early Jurassic intervals can be interpreted as reflecting the pillow phase of the diapirs which was followed by salt evacuation during the Bathonian-Portlandian, the rise of the diapir and the formation of a rim syncline during the Late Jurassic. Therefore, it is concluded that halokinetic movements were initiated during the Early Jurassic, resulting in the formation of salt pillows, and culminated by the end of the Jurassic with the rise of the diapirs and the development of rim synclines.

In the area of the Guercif Basin, a major hiatus spans Cretaceous to Middle Miocene times. However, in the southeastern part of the Middle Atlas, Cenomanian to Maastrichtian sediments are preserved (Fig. 2). Enclosure 3 clearly illustrated that the Mesozoic half graben, which underlies the Neogene Guercif Basin, was only mildly inverted prior to the transgression of the Tortonian and younger series. During these pre-Neogene inversion movements, the basement fault bounding the Debdou platform was reactivated; transpressional movements along this fault gave rise to the development of an anticlinal structure in the hanging-wall block, causing uplift and erosion of its Bathonian to Portlandian sedimentary cover.

Surface geological data from the southeastern Middle Atlas indicates the occurrence of pre-Maastrichtian inversion events (du Dresnay, 1988), which were followed by the commonly accepted Late Eocene event (Michard, 1976; Robillard, 1979; Ziegler, 1988). Therefore, it is reasonable to assume that the main inversion of the northeastern part of the Middle Atlas Trough had also occurred during the Late Senonian to Late Eocene time span. However, the extent to which this area had been covered by Late Cretaceous sediments prior to its inversions is unknown.

Subsidence of the Guercif Basin commenced with the transgression of Tortonian strata over truncated Jurassic series and persisted, under regressive conditions, through Messinian into Pliocene times. Basal conglomerates are followed by lacustrine shale and carbonates which are capped by Pliocene continental sands (Fig. 2).

The seismic profiles across the Guercif Basin, given in Fig. 7, show that its Tortonian subsidence was governed by extensional tectonics. As Messinian and Pliocene strata are not affected by tensional faults, rifting activity must have been of relatively short duration. The reflection configuration of Messinian strata indicates that they were deposited during a tectonically quiescent period. Convergence of Pliocene reflectors over structures, such as the one drilled by the well GRF1 (Fig. 7) and the Safsafat anticline, indicate that a compressional regime dominated the Pliocene evolution of the basin. During the Pliocene partial inversion of the basin, some of the Tortonian extensional faults were apparently compressionally reactivated. During this late compressional phase, the diapirs were reactivated to the extent that they now form outcropping elongated folds.

It is concluded that the area occupied by the Neogene Guercif Basin has undergone a plyphase evolution. Triassic to Early Jurassic crustal extension governed the subsidence of the Middle Atlas Trough. Tectonic instability continued during Middle and Late Jurassic times. Transpressional deformation of the Middle Atlas Trough commenced during the Late Senonian and culminated in its Eocene inversion. Tortonian extension governed the subsidence of the Guercif Basin. Messinian strata were deposited under a quiescent regime. Remobilisation of the Triassic salts under the overburden of thick Neogene sediments gave rise to the development of diapirs and domal structures. These features were modified during the Pliocene compressional phase. Pliocene compressional structures strike NE-SW and N-S.

CONCLUSIONS AND IMPLICATIONS FOR HYDROCARBON EXPLORATION

The Triassic-Jurassic grabens of northern Morocco form an integral part of the Western Tethys and North and Central Atlantic rift system. During the Alpine orogeny these grabens were inverted to various degrees. Eocene inversion of the Middle Atlas rift must be related to collisional coupling between the evolving Rif orogen and its foreland. The emplacement of the Prérifaine nappe at the transition from the Middle to the Late Miocene was accompanied by rapid subsidence of a relatively narrow foreland basin. Late orogenic phases of foreland compression resulted in the destruction of this foreland basin. Eocene inversion structures of the Guercif Basin involve compressional reactivation of tensional basement faults. In contrast, there is no evidence for basement reactivation during the development of the Messinian-Pliocene "Rides Prérifaines"; these are characterized by a major detachment system which soles out in Triassic evaporites, deposited in an extensional basin. South-verging thrusts are associated with east- and west-verging lateral ramps. All structures of the "Rides Prérifaines" are strongly influenced by the configuration of the Triassic-Early Jurassic rifted basin, the sedimentary fill of which was partly scooped out by Messinian-Pliocene thrust faulting.

The "Rides Prérifaines" contain significant hydrocarbon accumulations, contained in Late Neogene structures. During the Messinian-Pliocene deformation of the "Rides Prérifaines", hydrocarbons contained in pre-existing salt induced structural traps, were partly destroyed, thus releasing sizable volumes of oil for the charge of the newly formed structural traps. Early salt induced structures, which retained part of their closure during the late phases of basin deformation, may still contain significant amounts of hydrocarbons.

In the Guercif Basin, four exploratory wells were drilled on Pliocene structures all failed to encounter hydrocarbons. Eocene inversion structures are more likely to contain hydrocarbon in Mesozoic reservoirs, provided Early Jurassic source-rocks have attained maturity, as attested by oil seeps found the Middle Atlas (e.g. Issouka oil seep). Triassic-Jurassic extensional tectonics controlled the distribution of reservoirs, seals, source-rocks in half grabens and migration pathways of hydrocarbon generated. Generally, the footwall is dominated by relatively shallow water facies, such as carbonate build-ups, sand shoals and slope turbidites. The hanging wall is marked by ramp-type margin facies, including sand shoals and reefs.

Palaeotectonic basin analyses, based on an integration of surface and subsurface geological data, as well as structural and seismostratigraphic analyses of reflection seismic data, can greatly advance the understanding of the evolution of foreland basins and their hydrocarbon habitat.

Acknowledgments- The interpretations presented here were developed during the preparation of the author's Ph.D. thesis at *Rice University, Houston*, under the supervision of Prof. A.W.Bally, to whom he wishes to expresses his sincere thanks. The support of this research project by *ONAREP*, which provided the seismic and well data, and by *TOTAL*, which financed it, is gratefully acknowledged. Thanks are extended to Dr. P.A. Ziegler for his constructive and critical review of an earlier version of this manuscript and his editorial efforts.

REFERENCES

Ait Brahim, L. and P. Chotin (1984), "Mise en évidence d'un changement de direction de compression dans l'avant-pays rifain (Maroc) au cours du Tertiaire et du Quaternaire". *Bull. Soc. géol France*, **XXVI**, 4, pp. 681-691.

Beauchamp, J. (1988), Triassic sedimentation and rifting in the High Atlas (Morocco). In *Triassic-Jurassic Rifting, continental Breakup and the origin of the Atlantic Ocean and Passive Margins* (Edited by Manspeiser, W.), Elsevier, Amsterdam, Part A, pp. 477-497.

Bally, A.W. (1992), *Tectonic evolution of Morocco based on reflection seismic profiles*. Seminar sur la geologie pétrolière. (abstract).

Bernini, M., M. Boccaletti, J. El Mokhtari, R. Gelati, G. Moratti and G. Papani (1994), *The Neogene Taza-Guercif Basin. excursion guide book. Interim colloquium: Neogene basin evolution and tectonics in the Mediterranean area. Post congress excursion: The Neogene Taza-Guercif Basin.Excursion Guide Book. (April 10-12, 1994)*, 57 p.

Boccaletti, M., R. Gelati, G. Papani, M. Bernini, J. El Mokhtari and G. Moratti (1990), "The Gibraltar arc: an example of neoalpine arcuated deformation connected with ensialic shear zones". *Mem. Soc. Geol. It.*, **45**, pp. 409-423.

Choubert, G. and A. Faure-Muret (1962), Evolution du domaine Atlasique marocain depuis les temps paléozoiques. In *Livre mémoire P. Fallot, Mém. h. sér. Soc. géol. France*, **1**, pp. 447-527.

Colleta, B. (1977), *Evolution Neotectonique de la partie meridional du bassin de Guercif (Maroc oriental)*. Thèse de 3ème cycle. Université Scientifique et Médicale de Grenoble, 136 p.

Cousminer, H.L. and W. Manspeiser (1977), Autunian plynoflorules: contribution to the chronlogy and tectonic history of the Moroccan pre-Atlantic boarderland. In *Stratigraphic paleontology of Atlantic Basins and Borderland* (Edited by Swain, F.M.), Elsevier, Amsterdam, pp. 185-202.

Daguin, F. (1927), *Contribution à l'étude géologique de la région Prérifaines (Maroc occidental). Notes Service des Mines et de la Carte Géolgique, Maroc*, **1**, 413 p.

Dercourt, J., L.E. Ricou and Vrielinck (Eds.) (1993), *Atlas Tethys paleoenviromental maps*. Gautier-Villars, Paris, 307 p.

Du Dresnay, R. (1988), Recent data on the geology of the Middle Atlas (Morocco) In *Lectures Notes In Earth Science. The Atlas System Of Morocco*, Springer-Verlag, 462 p.

Durand Delga, M., L. Hottinger, J. Marçais, M. Mattauer, Y. Millard and G. Sutter (1960-1962), Données actuelles sur la structure du Rif. In *Livre a la mémoire du Professeur Paul Fallot. Mém. h. sér. Soc. géol. France.*

El Mokhtari, J. (1990), *Stratigraphia Del Basino Neogenico Di Taza-Guercif*. Dottorato Di Ricerca in Scienze Della Terra. Universita' Degli Studi Di Parma, Instituto Di Geologia, 172 p.

Emery, K.O and E. Uchupi (1984), *The Geology of the Atlantic Ocean*. Springer-Verlag, New York, 1050 p.

Faugère, J.C. (1978), *Les Rides Sud-Rifaines, Evolution sédimentaire et structurale d'un bassin Atlantico-Mésogeen de la marge Africaine*. Thèse de Doctorat D'Etat És Sciences, Université de Bordeaux 1, 481 p.

Favre, P., and G. Stampli (1992), "From rifting to passive margin: the examples of the Red Sea, Central Atlantic and Alpine Tethys". *Tectonophysics*, **215**, pp. 69-97.

Favre, P., G. Stampli and W. Wildi (1991), "Jurassic sedimentary record and tectonic evolution of the north western corner of Africa". *Palaeogeogr., Palaeoclima., Paleaoecol.*, **87**, pp. 53-73.

Fedan, B. (1988), *Evolution géodynamique d'un bassin intraplaque sur décrochements: Le Moyen Atlas (Maroc)durant le Meso-Cénozoique*. Thèse de Doctorat Es Sciences de Rabat. Université Mohame d v, Rabat. 338 p.

Flinch, J.F. (1993), *Tectonic Evolution of the Gibraltar Arc*. PhD Thesis, Rice University, Houston. 381 p.

Jacobshagen, V. (1988), *Geodynamic evolution of the Atlas system, Atlas system of Morocco*. Spring-Verlag, 462 p.

Laville, E. and A. Pique (1991), "La distension crustale atlantique et atlasique au Maroc au debut du Mésozoique, le rejeu des structures hercyniennes". *Bull. Soc. géol. France*, **162**, 6, pp. 1161-1171.

Levy, G.R. and R. Tilloy (1952), *Maroc Septentrional (chaine du Rif). Liveret-Guide des excursions A31 et C31. Congres géologique international, XIX session-Alger-1952, série Maroc*, **8**, 65 p.

Mattauer, M., P. Tapponnier, and F. Proust (1977), "Sur les mécanisme de la formation des chaines intracontinentales. L'exemple des chaines Atlasiques du Maroc". *Bull. Soc. géol. France*, **7**, XIX(3), pp. 521-526.

Michard, A. (1976), "Element de la Géologie marocaine". *Notes et Mém. Serv. Géol. Maroc*, **252**, 408 p.

Piqué, A. (1982), Structural domains of the Hercynian belt in Morocco. In *Regional Trends in the Geology of the Appalachian-Caledonian-Hercynian Mauretanide Orogen* (Edited by Schenk, P.E.), *NATO ASI SERIES C*, D. Reidel Publ. Co, Dordecht, Math. Phys. Sci., **116**, pp. 339-345.

Robillard, D. (1979), "Tectonique synsédimentaire du Moyen Atlas septentrional au Sud de Taza (Maroc)". *Bull. Soc. géol. France*, **7**, XXI(4), pp. 441-447.

Sutter, G. (1980a), "Carte géologique de la chaine rifaine. 1/500 000". *Notes et Mém. Serv. Géol. Maroc*, N° 245a.

Sutter, G. (1980b), "Carte structurale de la chaine Rifaine. 1/500 000". *Notes et Mém. Serv. Géol. Maroc*, N° 245b.

Van Houton, F.B. (1977), "Triassic-Liassic deposits of Morocco and eastern North America: a comparison". *Am. Assoc. Petrol. Geol. Bull.*, **61**, pp. 79-99

Wildi, W. (1983), "La chaine tello-rifaine (Algérie, Maroc, Tunisie): Structure, stratigraphie et évolution du Trias au Miocène". *Rev. Géol. Dynam. et de la Géogr. Phys., Paris*, **24**, 3, pp. 201-297.

Ziegler, P.A. (1988), *Evolution of the Arctic–North Atlantic and Western Tethys. Am. Assoc. Petrol.Geol. Mem.*, **43**, 198 p.

Ziegler, P.A. (1990), *Geological Atlas of Western and Central Europe, 2nd.Ed.* Shell Internationale Petroleum Mij. B.V., distrib. Geol. Soc., London, Publ. House, Bath, 239 p.

Enclosures

Enclosure 1 Seismic line P-12, Rides Prérifaines

Enclosure 2 Seismic line P-15, Rides Prérifaines

Enclosure 3 Seismic line G-17, Guercif Basin

Enclosure 4 Seismic line G-5, Guercif Basin